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LLNL-CONF-563994

Channel Modeling and Time Delay Estimation for Clock Synchronization Among Seaweb Nodes

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July 11, 2012

CRUSER and the 10th International Mine Warfare Technology Symposium
Monterey, CA, United States
June 8, 2012 through June 8, 2012

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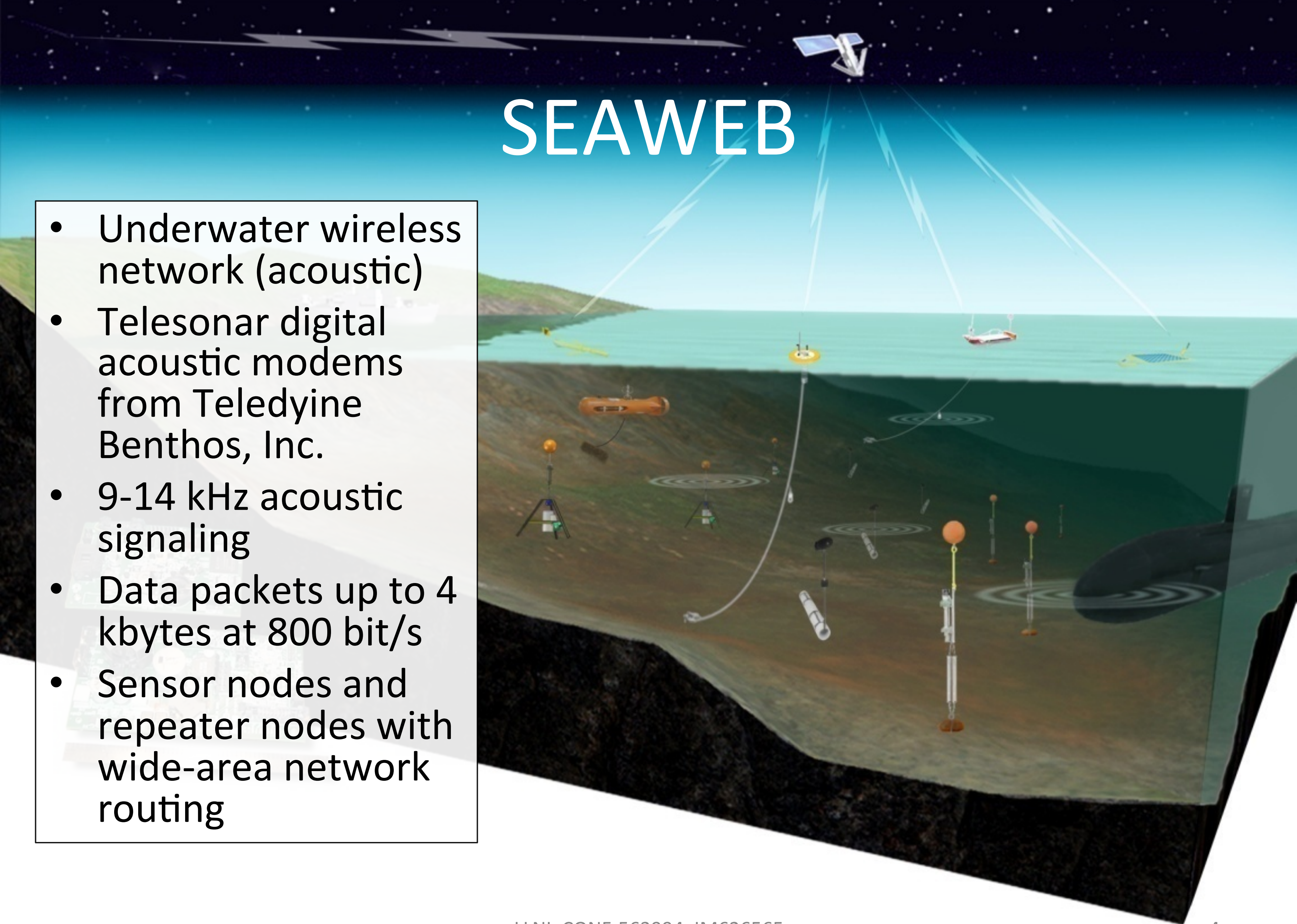
For: CRUSER and the
10th International Mine Warfare Technology Symposium
8 June 2012

Auspices:
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory in part under Contract W-7405-Eng-48 and in part under Contract DE-AC52-07NA27344.

Introduction

- Seaweb
- Clock-Synchronization
- Through-water challenge
- Published protocols
- Impulse response evaluation
- Simulation and Experimental results
- Conclusion



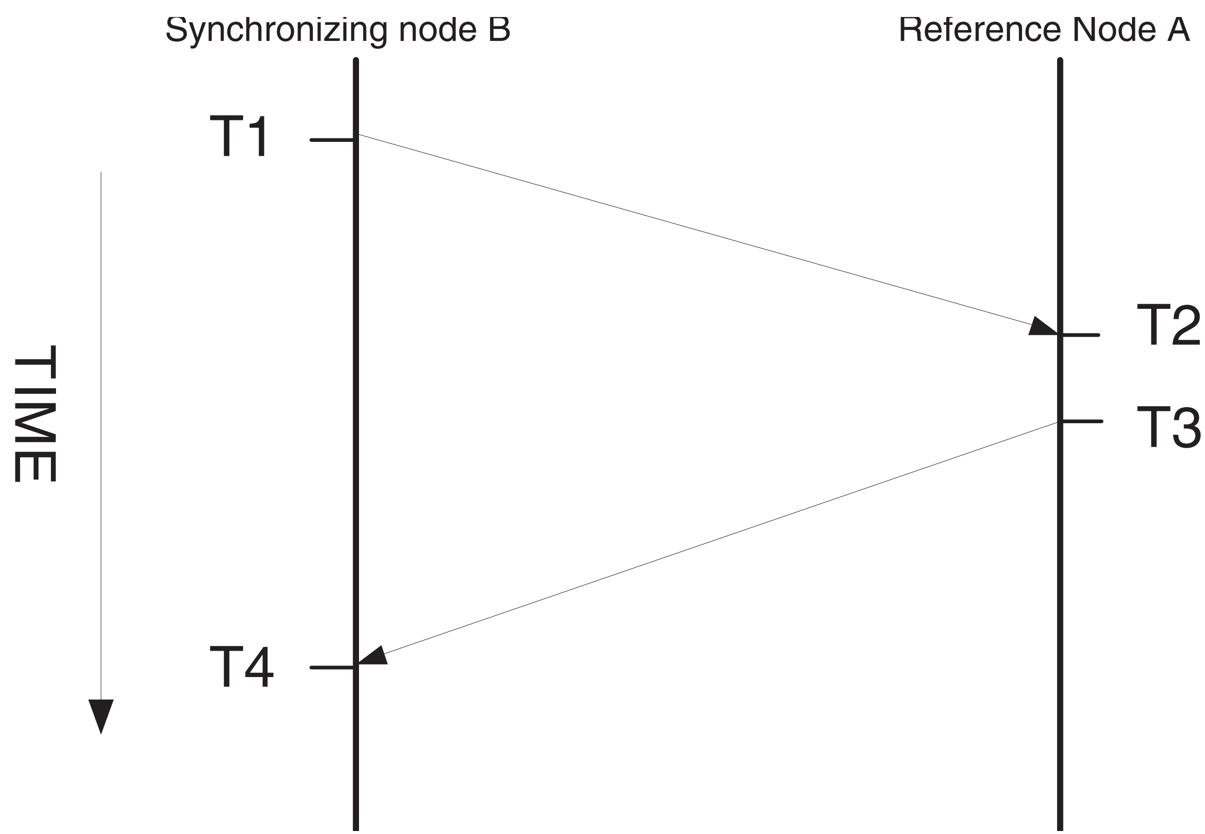
SEAWEB

- Underwater wireless network (acoustic)
- Telesonar digital acoustic modems from Teledyine Benthos, Inc.
- 9-14 kHz acoustic signaling
- Data packets up to 4 kbytes at 800 bit/s
- Sensor nodes and repeater nodes with wide-area network routing

Clock Synchronization

- Clock-synchronization = Time-Synchronization
- Each nodes have their own internal clock
- Quartz crystal based. Affected by:
  - Temperature
  - Pressure
  - Voltage changes
  - Hardware aging
- Important for:
  - Data Fusion
  - Power Management
  - Transmission Scheduling (TDMA)
- Energy consideration

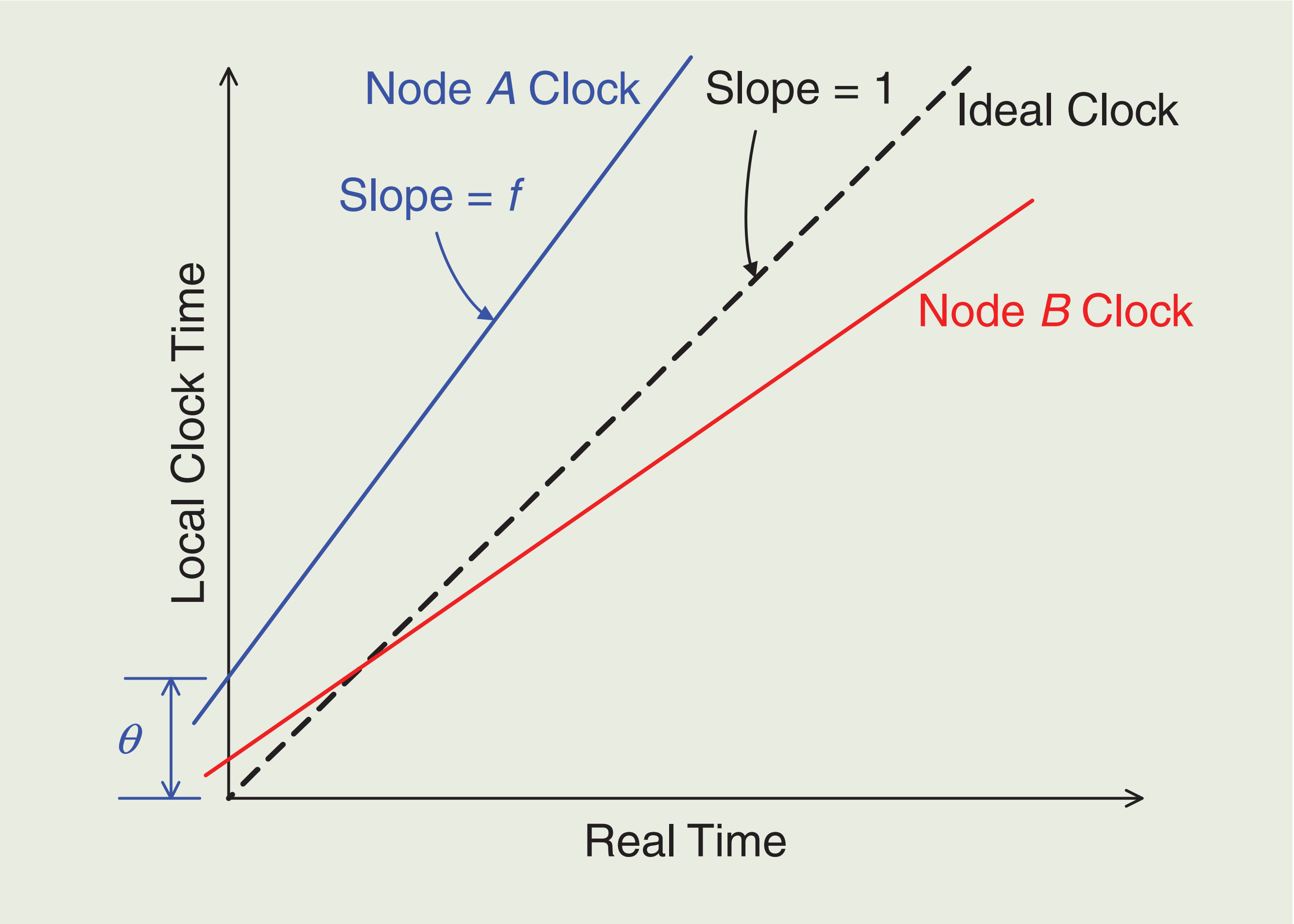
Time-Stamped message exchange



Propagation Delay = [(T2-T1) + (T4-T3)]/2.

A. Syed, and J. Heidemann, "Time Synchronization for High Latency Acoustic Networks", *Proceedings IEEE Infocom*, Barcelona, Spain, 2006.

Skew and Offset



Y.C. Wu, Q. Chaudhari, and E. Serpedin, "Clock Synchronization of Wireless Sensor Networks", *IEEE Signal Processing Magazine,* pp. 124 – 138, Jan. 2011.

The through-water challenge

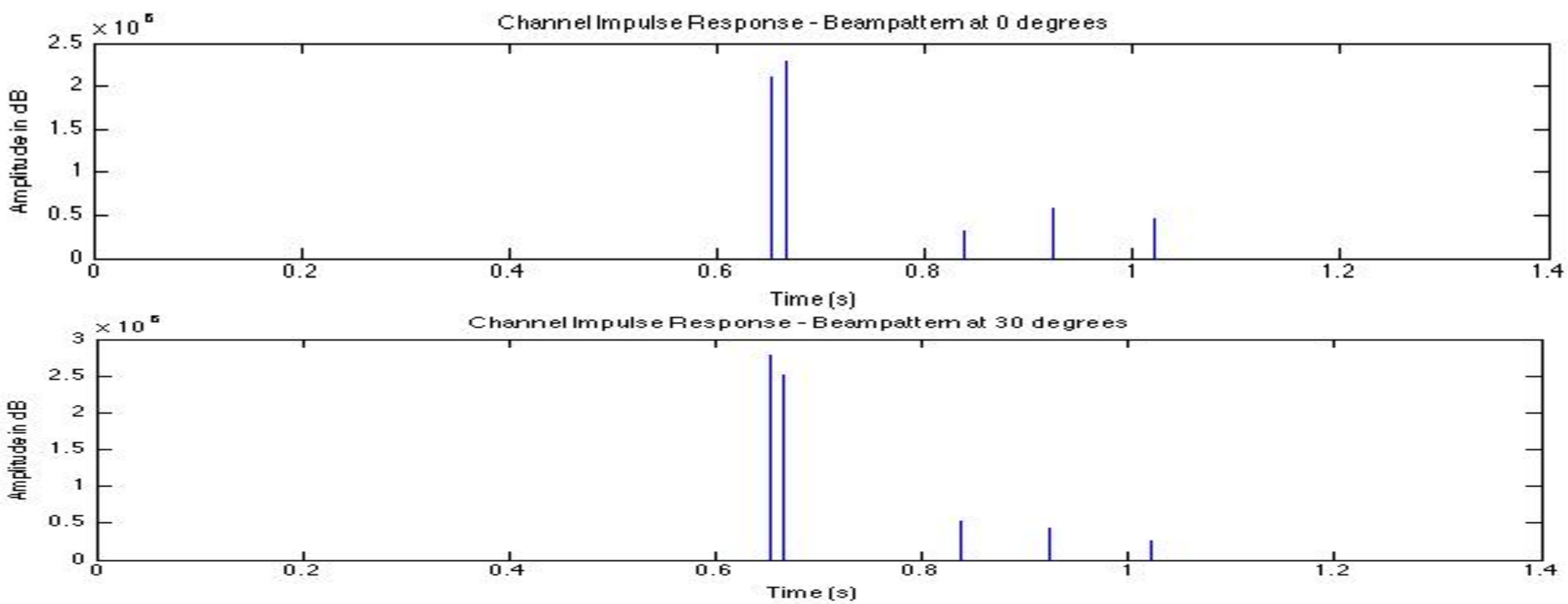
- Time delay estimation
- The propagation medium is an impaired channel compared to radio waves:
  - High Latency
  - Multipath
  - Scattering
  - Refraction
  - Transmission loss
  - Noise
- Affects the Impulse response of the communication channel
- Existing clock-synchronization techniques assume a time invariant medium over a short period of time

Proposed Clock Synchronization protocols

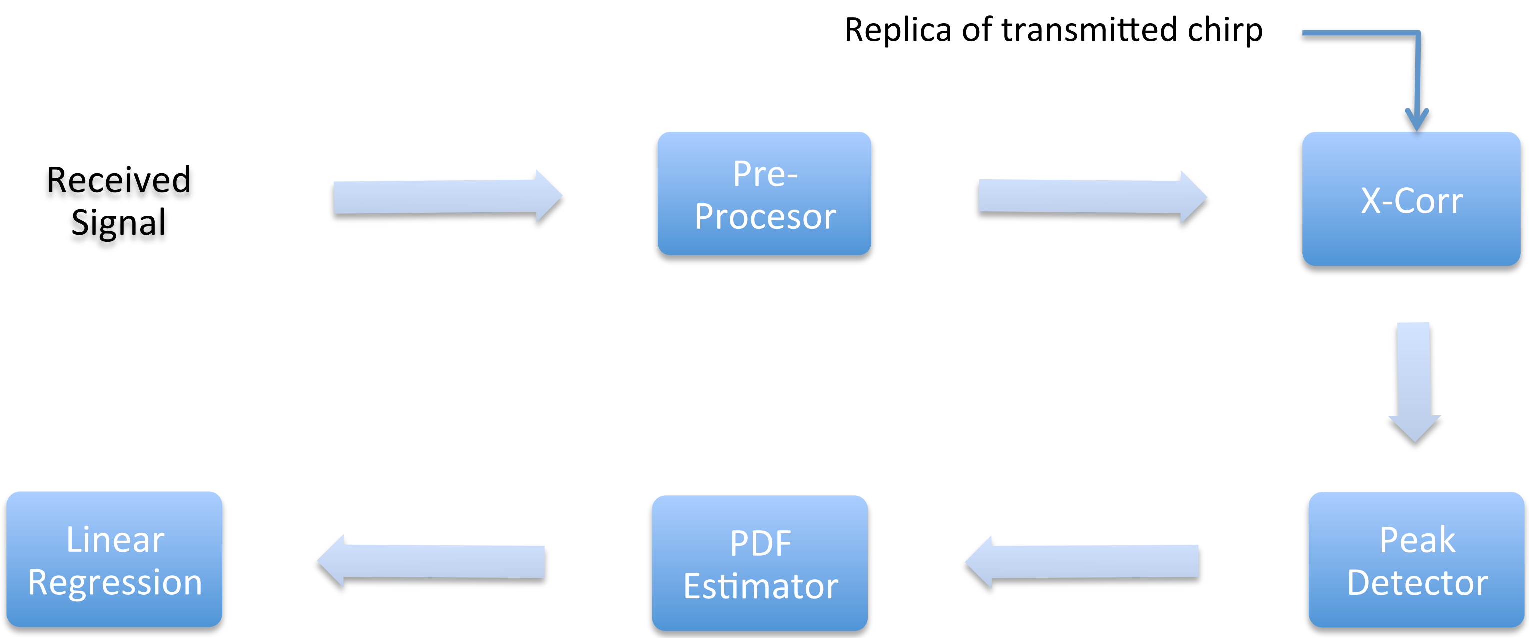
- Time Synchronization for High Latency Networks(TSHL)
  - Assumes fix nodes
  - 2 phases approach
- Mobi-Sync
  - Assumes moving nodes
  - Multiple nodes synchronization
- Modified TSHL using feasibility checked least squares estimator with a Paxson-based estimator
  - Series of 2-way message exchange
- Lots of simulation but not many system experimentation.
- Unrealistic assumptions

Impulse Response Evaluation

- Based on prior-experimentation, impulse response can vary.
- Keeping track of the impulse response



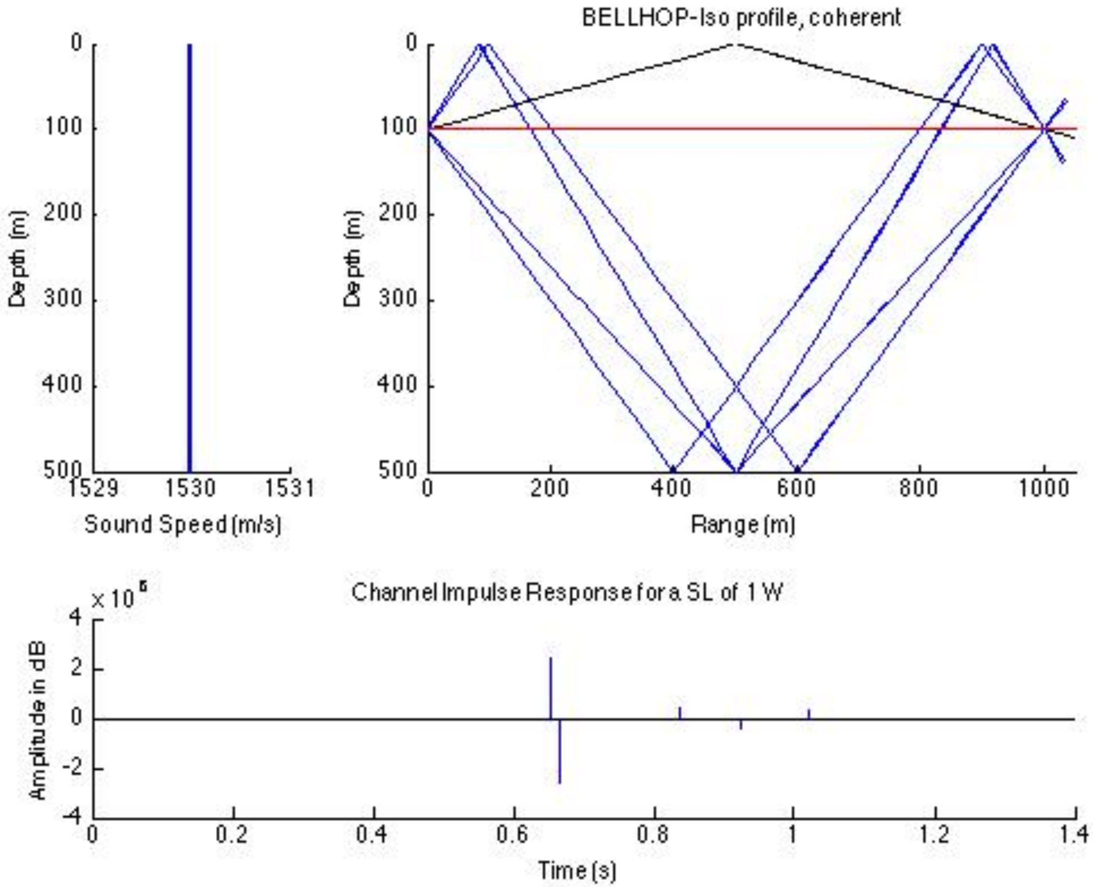
Proposed model



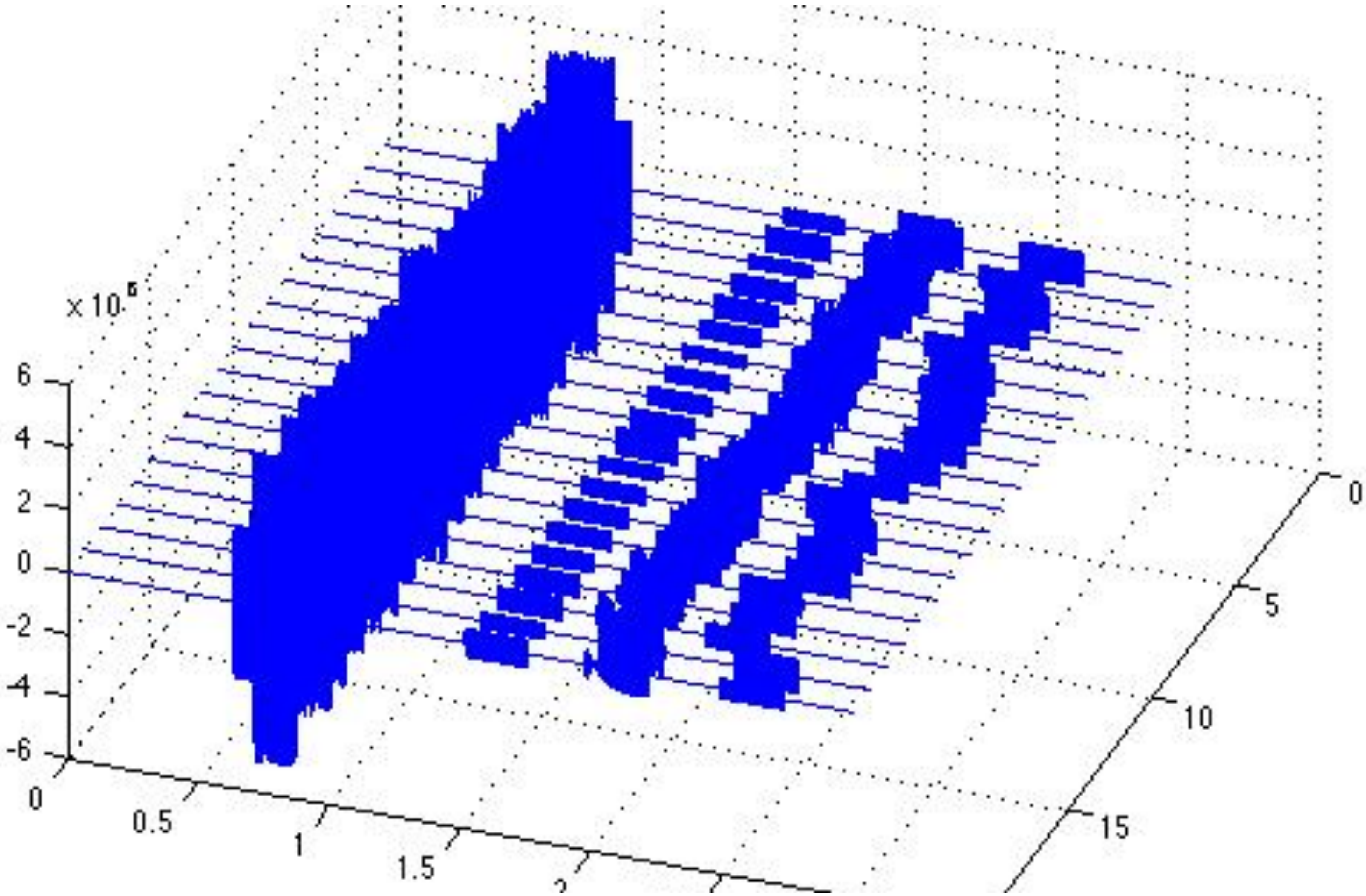
Simulation

- Generate 20 pulses while varying:
  - Angle of transmitter
  - Phase of surface wave
- Bellhop
  - Ray Tracing program
- virTEX
  - Takes into account the effects of multipath and doppler introduced by environmental motion

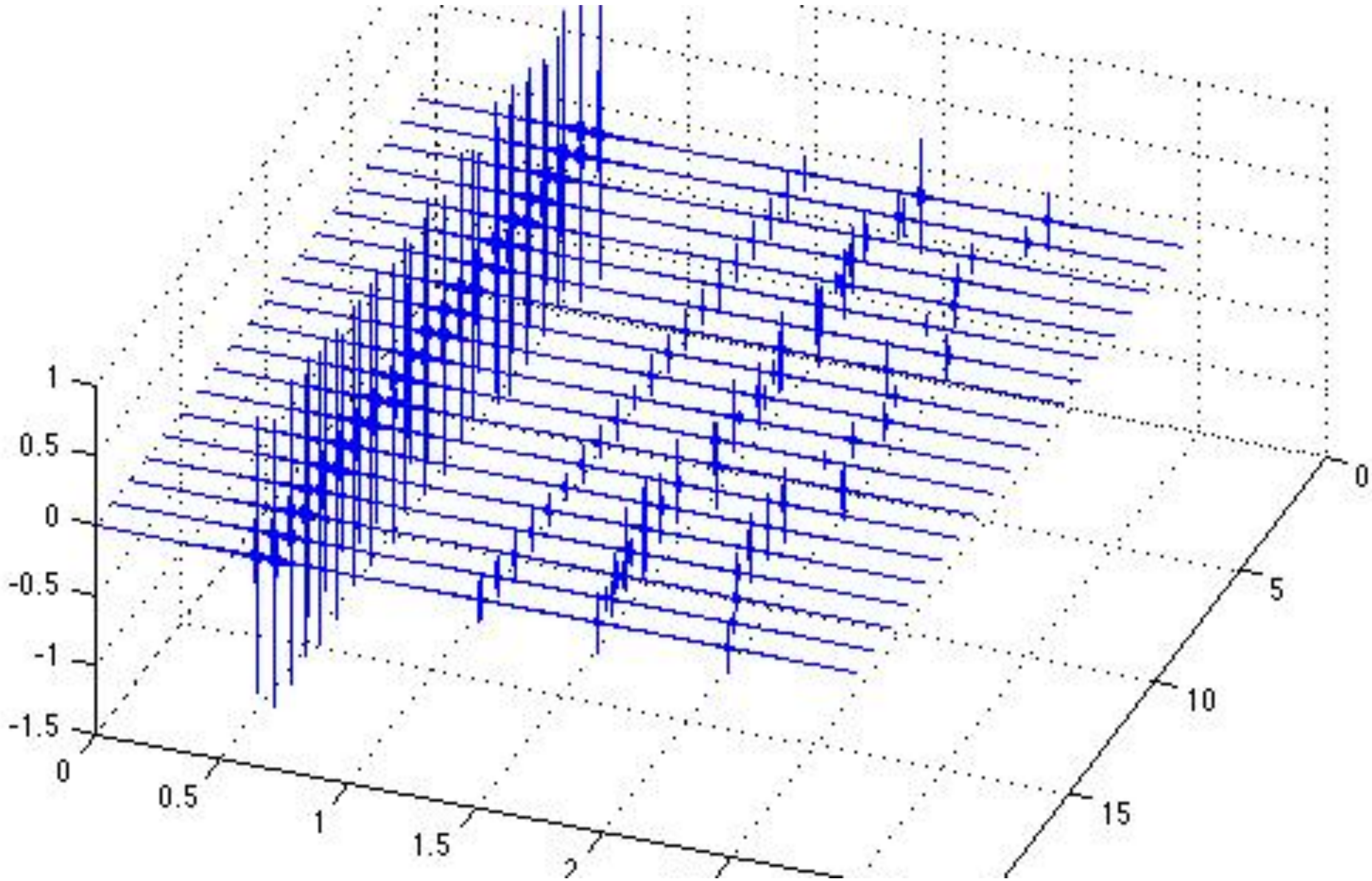
Simulation Characteristics



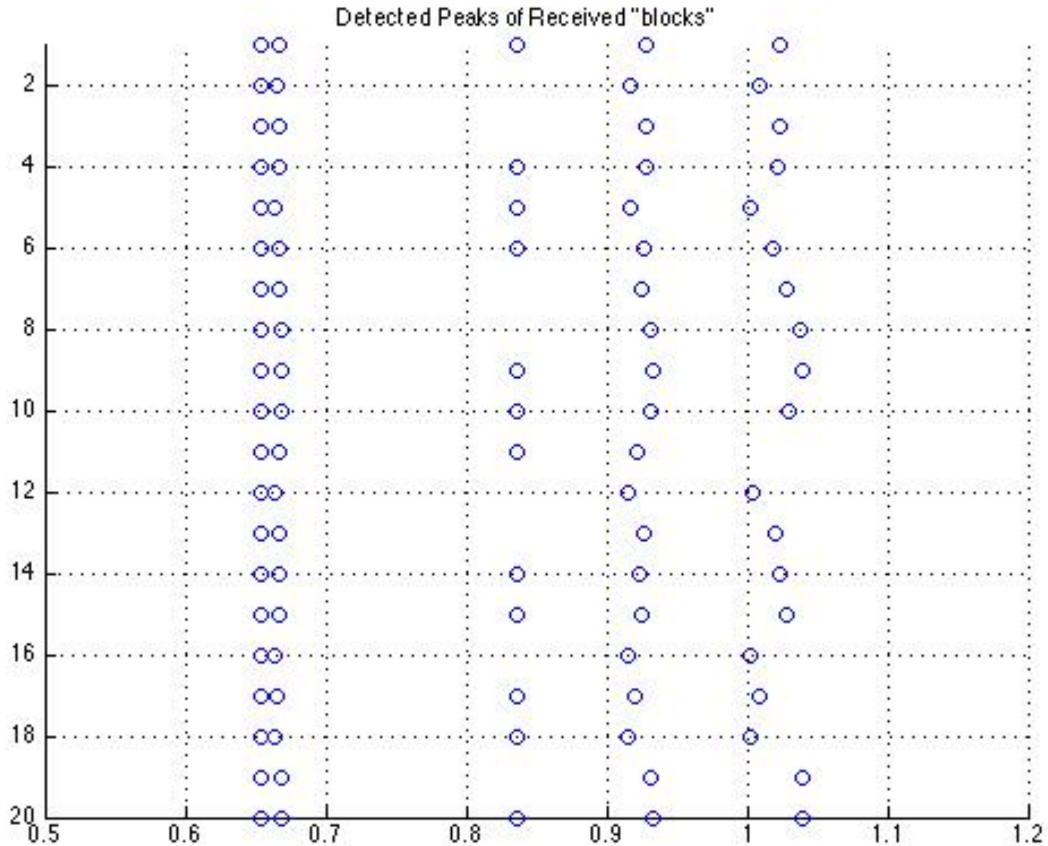
Simulation results – Received Signal



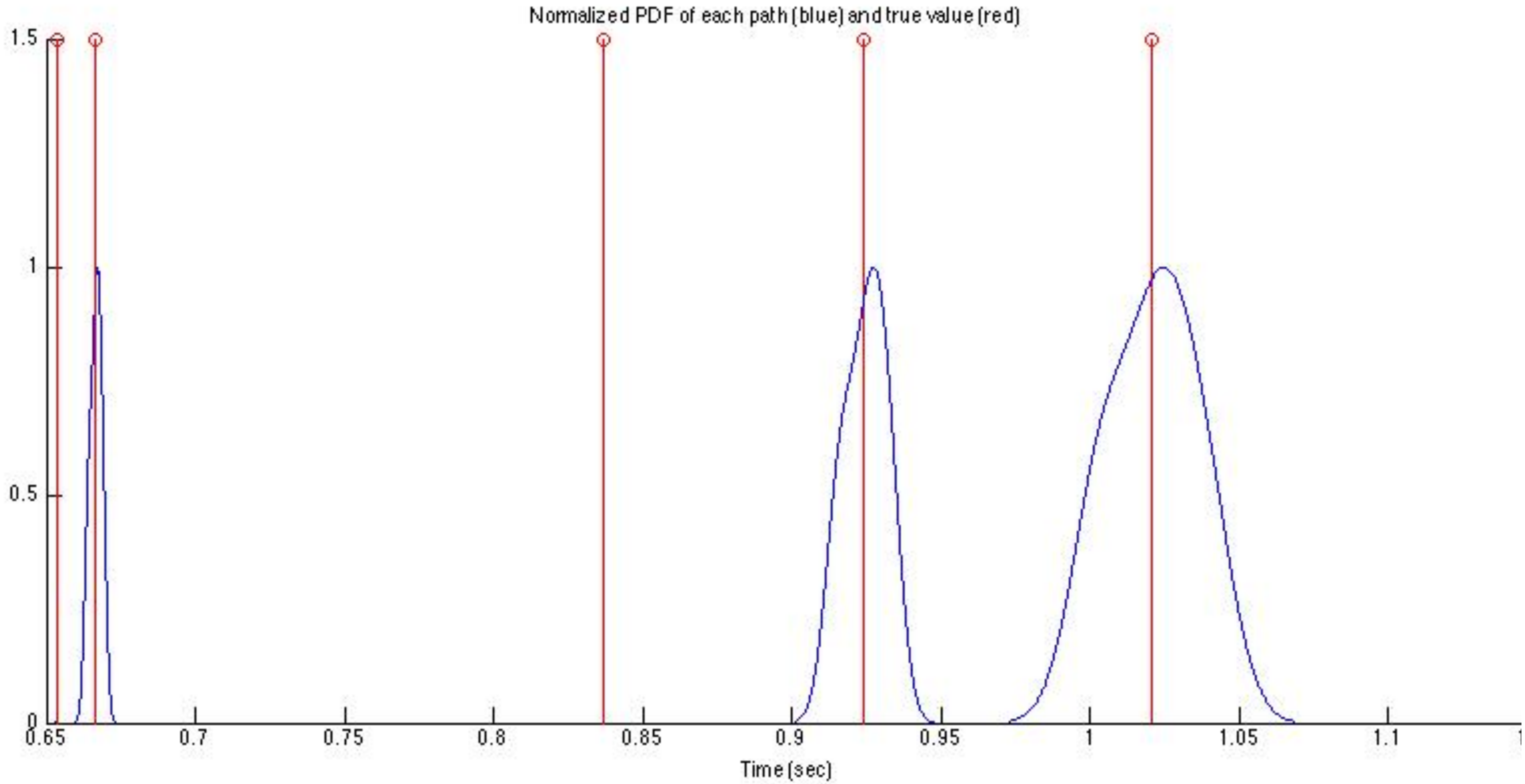
Simulation results – X-Correlated signal



Simulation result – Peak detection



Simulation Result – PDF of impulse response



Lake Del Monte Experiment

- SM-75 and Deck Box
- Series of 30 pulses
- Various pulse length and PRI

Ongoing Research

- Finalizing simulation and algorithms
- Analyzing Experimental data
- Potential additional experimentation
- Sep 2012: Publication of MS thesis

Conclusion

- From simulations, tracking of the impulse response is feasible.
- Potential to benefit other functions such as ranging between two nodes.
- Potential to combine the features of different protocols to create a new and more realistic clock-synchronization protocol.

References

[1] Y.C. Wu, Q. Chaudhari, and E. Serpedin, "Clock Synchronization of Wireless Sensor Networks", *IEEE Signal Processing Magazine,* pp. 124 – 138, Jan. 2011.

[2] A. Syed, and J. Heidemann, "Time Synchronization for High Latency Acoustic Networks", *Proceedings IEEE Infocom*, Barcelona, Spain, 2006.

[3] J. Liu, Z.Zhou, Z. Peng, and J.-H. Cui, "Mobi-sync: efficient time synchronization for mobile underwater sensor networks", *WuWNET '09: Proceedings of the fourth ACM international workshop on Underwater Networks*, New York, USA, 2009.

[4] J. Pettyjohn, D. Jeske, and J. Li, "Least Squares-Based Estimation of Relative Clock Offset and Frequency in Sensor Networks with High Latency", *IEEE Transactions on Communications*, Dec. 2010.